Master Thesis Call

Comparative Analysis of HYDRUS-1D Model Simulations Using ERA5 Remote Sensing Data and Field-Based Soil Hydrodynamic Parameters in the Merbitz Region, Germany

Duration: 6 Months
Objective: To evaluate the potential of using ERA5 remote sensing data as a substitute for field-based soil hydrodynamic parameters in HYDRUS-1D model simulations, focusing on soil moisture dynamics in the Merbitz region, Germany.
Thesis Overview:
This thesis will investigate the feasibility of replacing traditional field measurements with remote sensing data, specifically from the ERA5 dataset, in simulating soil moisture dynamics using the HYDRUS-1D model. The study will focus on the Merbitz region, where both soil moisture data and field-based soil hydrodynamic parameters are available. The primary objective is to compare the accuracy and reliability of HYDRUS-1D simulations based on field-collected soil hydrodynamic parameters versus those derived from ERA5 data.

Key Areas of Work:

- **Data Collection and Preprocessing:**
  The candidate will gather soil hydrodynamic parameters from field sampling in the Merbitz region, which have already been calculated using the van Genuchten model. Additionally, relevant ERA5 remote sensing data, such as soil moisture and other hydrological variables, will be collected. The data will undergo detailed preprocessing, including extraction, cleaning, and spatial-temporal alignment to ensure compatibility with the HYDRUS-1D model.
- **HYDRUS-1D Model Setup and Calibration:**
  The candidate will set up the HYDRUS-1D model using the field-based soil hydrodynamic parameters calculated from the van Genuchten model. The model will be calibrated against observed soil moisture data from the Merbitz region to ensure accurate simulations. Calibration will focus on optimizing key model parameters to align simulated outputs with the observed data.
- **Simulation Using ERA5 Data:**
  Once the baseline model is established using field-based parameters, the candidate will replace these with hydrodynamic parameters derived from ERA5 remote sensing data. The HYDRUS-1D model will then be rerun with this new input to assess the performance and reliability of simulations using remote sensing data.
- **Comparative Analysis of Simulation Results:**
  A detailed comparative analysis will be conducted between simulation results using field-based parameters and those derived from ERA5 data. The candidate will utilize statistical measures such as RMSE, MAE, and correlation coefficients to quantify differences and evaluate the reliability of ERA5 data as a substitute for field-based measurements.
- **Validation Using Available Soil Moisture Data:**
  The simulation results will be validated against observed soil moisture data from the Merbitz region. This step will help identify any discrepancies and provide insights into the accuracy of the HYDRUS-1D model when remote sensing data is used.
- **Interpretation of Results and Implications:**

The candidate will interpret the results, focusing on the implications of using remote sensing data instead of field-based measurements in hydrological modeling. The potential for ERA5 data to reduce the need for extensive fieldwork in soil moisture studies will be critically assessed, and recommendations for future applications will be made.

Expected Outcomes:

- **Evaluation of ERA5 Data as a Substitute for Field Measurements:**
  A detailed assessment of the potential for using ERA5 remote sensing data to replace field-collected soil hydrodynamic parameters in HYDRUS-1D simulations, with an analysis of the trade-offs and benefits.
- **Improved Understanding of Soil Moisture Dynamics:**
  Insights into soil moisture dynamics in the Merbitz region, highlighting how different data sources influence the accuracy and reliability of hydrological models.
- **Guidelines for Integrating Remote Sensing Data into Hydrological Models:**
  Development of practical guidelines for effectively integrating remote sensing data into hydrological models like HYDRUS-1D, potentially reducing the need for labor-intensive field measurements.
- **Recommendations for Future Research and Applications:**
  Recommendations for future research directions and practical applications in hydrology, particularly in regions where field data collection is challenging or resource-intensive.

Who Should Apply:

This thesis is ideal for students with a background in hydrology, environmental science, geoinformatics, or related fields, with a strong interest in hydrological modeling, remote sensing, and data analysis. Applicants should have experience with modeling tools (preferably HYDRUS-1D), programming languages such as Python or R, and a solid understanding of geospatial data processing. Familiarity with the van Genuchten model and statistical analysis will be advantageous.

Contact Information:

For more information, please contact Dr. Muhammad Usman (muhammad.usman@geo.uni-halle.de) at the Department of Geoecology.

Monthly Work Plan

Month 1: Literature Review and Preliminary Setup

- **Week 1-2: Literature Review**
  - Conduct an in-depth review of existing literature on soil moisture modeling, the use of HYDRUS-1D, remote sensing data (particularly ERA5), and the van Genuchten model.
  - Identify key studies and methodologies that are relevant to the thesis topic.
- **Week 3-4: Data Collection and Preprocessing**
  - Gather all necessary data:
    - Soil hydrodynamic parameters from field sampling in the Merbitz region.
    - ERA5 remote sensing data relevant to soil moisture and hydrological modeling.
  - Start preprocessing the data:
    - Clean and align the field data and ERA5 data spatially and temporally.

Month 2: Model Setup and Calibration (Field-Based Parameters)

- **Week 1-2: HYDRUS-1D Model Setup**
  - Set up the HYDRUS-1D model using the field-based soil hydrodynamic parameters.
  - Implement the van Genuchten model within HYDRUS-1D.
  - Input initial boundary conditions and other relevant parameters.
- **Week 3-4: Model Calibration**
  - Calibrate the HYDRUS-1D model using the field-based soil moisture data.
  - Adjust model parameters to achieve the best fit between simulated and observed data.
  - Perform initial simulation runs and analyze preliminary results.

Month 3: Simulation Using ERA5 Data

- **Week 1-2: ERA5 Data Integration**
  - Replace field-based soil hydrodynamic parameters in the HYDRUS-1D model with those derived from ERA5 data.
  - Ensure that the ERA5 data is correctly formatted and integrated into the model.
- **Week 3-4: Simulation Runs**
  - Run the HYDRUS-1D model using ERA5-based parameters.
  - Conduct multiple simulation runs to test the model under different conditions.

Month 4: Comparative Analysis

- **Week 1-2: Statistical Analysis**
  - Perform comparative analysis between simulation results obtained from field-based and ERA5-based parameters.
  - Use statistical measures such as RMSE, MAE, correlation coefficients, and others to quantify differences.
- **Week 3-4: Validation Against Observed Data**
  - Validate the simulation results against observed soil moisture data from the Merbitz region.

- Identify and document any discrepancies or notable findings.

Month 5: Interpretation and Documentation

- **Week 1-2: Interpretation of Results**
  - Analyze the implications of using ERA5 data in place of field-based measurements.
  - Assess the reliability and accuracy of the HYDRUS-1D model with remote sensing data.
- **Week 3-4: Report Writing – Initial Draft**
  - Begin drafting the thesis, focusing on methodology, results, and discussion sections.
  - Include detailed descriptions of the modeling process, comparative analysis, and key findings.

Month 6: Finalization and Defense Preparation

- **Week 1-2: Refinement and Final Analysis**
  - Refine the thesis draft based on feedback from the supervisor.
  - Conduct any additional analysis if required.
  - Finalize all figures, tables, and statistical analyses.
- **Week 3-4: Thesis Submission Preparation**
  - Complete the final draft of the thesis.
  - Ensure that all sections, including the introduction, literature review, and conclusion, are well-integrated and cohesive.
  - Prepare appendices and references.